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COMPUTERIZED GAS METERING SYSTEMS

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DISCLAIMER

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INTRODUCTION

The personnel of the High Pressure Laboratory have successfully built two computerized gas metering systems with data acquisition for testing vessels up to 19,000 psi. This unique system is needed for tests which require precise control of pressure and/or pressurization rate such as acoustic emission or holographic tests. With a computer-controlled metering valve set dynamically, a wide range of volumes and pressure rates are allowed. In addition, data acquisition for measurements other than system pressure is provided. Finally the software shortens the time needed to setup and calibrate the transducers of the system and test vessel.

The control software compensates for the wide differences of vessel volumes that may be tested. For a typical test using a 500 cc vessel, the rate of pressurization can vary from 25 to 5000 psi/min. Positive, negative, and zero pressurization rates can be used. Vent with data acquisition may also be selected as part of the gas profile. Furthermore, the profile can start at a preselected pressure because the test vessel can be initialized to this prescribed pressure before running a test.

The computer automatically stores the system pressure and the displacement of the metering valve on the data acquisition disk. Besides these system transducers, an experimenter has 26 high level and 12 low level transducers available for vessel instrumentation. All high level channels can be scanned 60 times/sec and all low level channels can be scanned once each second. Approximately 200,000 total measurements can be taken and stored during each test.

To help an experimenter monitor a test, three displays are available. First up to eight real-time curves can be plotted on a single grid. Second current values from all the transducers are tabulated. Third a system diagram shows the positions of the on-off valves and the pertinent parameters such as desired pressure, desired rate, actual pressure, and actual rate. Whenever pressure exceeds approximately 100 psi in any of the tubing, the tubes light up on this diagram.

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FEATURES OF AN AUTOMATED GAS METERING SYSTEM

Type of Gas

For System 1 only helium gas is allowed. With System 2, an operator may select either helium or deuterium gas. At present both systems operate with a source pressure of 20,000 psi. They are easily connected to a "house" supply rated at 30,000 psi.

With deuterium gas, extra safety features are included to minimize the mixing of air and flammable gas. The test vessel is placed inside a containment vessel. Then this containment vessel is filled with argon gas before running a test. If a burst or a leak occurs, the experiment will automatically be stopped, the valve from the gas supply will be closed, and the system and containment vessel will be vented.

Automatic Control of Pressure Profile

A gas profile consists of up ramps, down ramps, two type of holds, and a vent. Up to 60 different segments may be used to describe a profile. For each ramp, the flow rate should be between 25 to 5000 psi/min for a 500 cc vessel. If a vessel is less than 100 cc, an auxiliary volume of 100 cc is placed in parallel with the test vessel.

For a hold, an experimenter has the option of either a "normal" hold which is to maintain a prescribed pressure or a "hard" hold which closes the appropriate valves and terminates the flow of gas. With normal hold following an up ramp profile, a vessel may only be filled. If it follows a down ramp, a vessel may only be depressurized. The rationale for this method of control is to minimize limit cycles in the flow of gas.

The software program uses the maximum vessel pressure to select one of the five system's pressure transducers. This is shown in the following table:

Table 1

Selection of System's Transducers

maximum vessel pressure (psi)	system's transducer
pressure <= 1900	2K
1900 < " <= 4750	5K
4750 < " <= 9500	10K
9500 < " <= 19000	20K
19000 < " <= 30000	30K

A typical pressure profile is shown in Figure 2.1. The test vessel is pressured to 5000 psi at a rate of 1000 psi/min. At the end of this segment, the computer will maintain this pressure for 3 minutes (normal hold). Then the flow of gas will stopped for 2 minutes (hard hold). The test vessel will now be depressurized at a rate of 1000 psi/min for 2 minutes. Finally it will be vented with data acquisition for another minute.

The central component of the gas metering system is a computerized metering (Annin) valve that can be dynamically set to whatever pressurization rate is desired. This precise control provides greater accuracy than can be achieved by manual methods of valve operation.

Data Acquisition

A maximum of 38 channels for data acquisition is available. These channels are connected to the computer through two 12-bit analog-to-digital (A/D) converters. The fast A/D converter has 26 channels available to the experimenter and can acquire data at a rate of 500 samples/sec for all channels. It has a fixed gain of 2 which allows input voltages between -5 to +5 volts. The slow A/D converter has 12 channels. Each channel can be scanned at a rate of 20 samples/sec or 50 millisecond between scans. As more channels are used, the time betwwen scans increases linearly. The gains and maximum input voltages to the slow A/D converter are shown in the following table:

Table 2

Gains and Voltage Ranges for Slow A/D Converter

Gain	Voltage Inputs
1	+ 10 volts
10	+ 1 volt
100	+ 100 millivolts
500	+ 20 millivolts

Real-Time Displays

The status of an experiment can be monitored at any time by viewing the real-time displays. For example, a system diagram (Fig. 2) can be displayed to show the current valve control status or a plot of transducer values versus time or another transducer (Fig. 3) may be called up. Also, a tabular display of the current values of all the instrumentation transducers (Fig. 4) may be viewed when desired. One of these three displays is shown by pressing the approriate key which is shown in the lower part of Figure 2. These keys are S5 (upper case F5), F5, and F11. Pressing key S5 shows the system's diagram while pressing keys F5 and F11 show the plot and the table of values respectively.

Figure 3 shows the results of a real-time plot. If multiple curves are desired, the vertical and horizontal axes are scaled accordingly with the scale factors tabulated below the graph. Curve 1 is the pressure of the system versus time. It follows the desired profile except for the last segment. This portion of the profile is a vent without control which occurs very rapidly. The plateau at 5000 psi corresponds to a 2 minute normal hold and a minute of hard hold. Curve 2 is the displacement of the metering valve in mils while curve 3 is the temperature in degrees centigrade of the tube which is connected to the test vessel. Finally curve 4 is strain (microinches/inch) versus pressure.

A table of current transducer readings is shown in Figure 4. The acronyms LVDT and PRESS stands for the stem displacement of the metering valve in mils (linear voltage differential transformer) and pressure of the system in psi respectively. Channels S0 and S1 are thermocouples calibrated in degrees centigrade, channels S2 and S3 are strain gauges in microinches/inch, channel 4 is pressure in psi, and channel S5 is displacement of the test vessel in mils.

Operator Interactions

There are eight states which describe an experimental run. These eight states are the other eight keys as depicted in the system's diagram (Fig. 2). These states for System 2 are:

1 Suspend
2 Start
3 Initialize Pressure
4 Restart
5 Add Ramp
6 System-Vent-End
7 Return-to-Start
8 Argon-Vent-End

After an experimental run is initialized, i.e. the pressure profile and the desired plots have been entered into the computer, the computer begins the experimental run routines. It begins in the suspend state which closes all the valves and opens if necessary an appropriate valve to enable a system's transducer and the valve to an auxiliary vessel.

To start a test, the start key is pressed. When the start state is entered, the stem displacement of the metering valve will be controlled. After the end of the pressure profile the system will vent automatically.

A summary of each of these states for System 2 is listed as follows:

Suspend (F7 key) - Initially the system is in the suspend state, i.e. no data acquisition, all valves are closed except the valve to the appropriate pressure transducer. Each time the suspend state is entered from the keyboard, two additional ramps are created. The limit of this system is 60 ramps. The test can be resumed by pressing the restart key F9.

Start (F6 key) - Pressing the F6 key starts the test by beginning to control the metering valve and to acquire data. At the end of the pressure profile, it will automatically go to the system-vent-end or suspend state. For most runs, the system-vent-end state is automatic. However if a ramp is added during a run, at the end of a resume state, the suspend state will be entered. The automatic vent can be suppressed by changing the "automatic end" option of the experimental parameter menu. Normally this option is not changed by the operator. However if it is changed, the suspend state will be entered automatically after a run.

Initialize Pressure (S6 key) - A vessel can be initialized to a predetermined pressure before starting a run. No data is taken during this initialization period.

Resume (F9 key) - A test can be resumed if it has been suspended. At the end of the pressure profile, it will automatically go to the system-vent-end or suspend state.

Add Ramp (F10 key) - If a run has been suspended, a new ramp can be added by specifying its time interval and final pressure point. The remainder of the profile is lost. To continue the test, press the resume key, F9. After the end of this ramp, the computer will automatically go to the suspend state. Another ramp can be entered or the test can be ended by pressing either the system-vent-end key, F8, or the argon-vent-end key, F12.

System-Vent-End (F8 key) - This state is entered automatically from a start or resume state or by pressing the system-vent-end key. When a test run is over, the system is vented and all data acquitition files are saved for processing.

Return-to-Start (S12 key) - This state will vent a test and save all data files. The operator will be asked if the experiment is to be repeated. The current test may be repeated or ended at this point.

Argon-Vent-End (F12 key) - An experimental run can be aborted at any time if the operator suspects a burst or a slow leak has occurred. In order to ensure saftey and prevent particles of a test vessel to enter the tubes of the system, the containment vessel is vented first, then the system is vented.

The keys to control the states are the function keys of the Tektronix 4025A terminal. The prefix S means press shift (upper case) simultaneously with the appropriate key, thus S6 key means press shift and the F6 key at the same time to initialize the system. The system diagram shows the positions of each key.

Post-Experimental Plots

After an experimental run, post-experimental plots of the data can be made. Any transducer versus time or any other transducer may be plotted. Also multiple curves may be drawn on a single set of grids. Besides linear axes, an experimenter has other choices such as semi-log or log-log grids. Furthermore expanded views of any section of the curve can be made.

Figure 5 shows the system pressure versus time. The pressure follows the desired profile except for the last segment which is a vent. Figure 6 shows the data from the two thermocouples plotted against time. The higher of the two temperature readings is the temperature of the tube which is attached to the test vessel (curve 1) while the lower one is the temperature of the vessel (curve 2). This temperature is fairly constant because the rate of pressurization (500 psi/min) is low. However during a vent operation, the temperature drops precipitously.

Calibration of Transducers

Any transducer for either the system or vessel instrumentation is easily calibrated by either (1) shunt calibration, (2) known inputs, or (3) manual entry. With shunt calibration, a shunt resistor is placed across one of the legs of a bridge network to produce an output voltage equivalent to a specific value of physical units. When the shunt resistor is removed, the physical unit is entered. With it present, the new value is entered. This is the method used to calibrate the five pressure transducers of the system.

With known inputs, two reference voltages with known physical units must be entered sequentially. The first known voltage is applied to the A/D converter and its physical units are entered into the computer. This procedure is repeated with a different voltage. These known reference voltages can be entered by either stimulating the transducer with its desired physical value or applying the known voltages directly to the A/D converters. The displacement of the metering valve is calibrated by (1) setting it to zero to obtain the first reference voltage and (2) inserting a 0.015 shim under the displacement transducer tip to obtain the second reference voltage.

Calibration by manual entry is broken into two types, bridge or active. With a bridge network, (1) excitation voltage, (2) the offset voltage in millivolts, and (3) sensitivity (millivolts/volt/physical unit) are entered into the computer. For an active type transducer, (1) offset in millivolts and (2) sensitivity (volts/physical unit) are entered into the computer. These values are usually obtained from calibration sheets or charts.

CONCLUSION

A computer can pressurize a vessel with either helium or deuterium gas to follow a prescribed profile. The computerized systems control pressure and flow more precisely than manually operated methods. With a real-time feedback loop monitoring the pressure and adjusting the metering valve setting, pressure can be increased, decreased, or held constant at the exact pressurization rate desired.

The data acquisition feature is more convenient than the old analog method. The digitized data can be displayed graphically in real time to monitor the progress of the test. The data stored on floppy disk can be processed and plotted. Magnified views of any transducer may be plotted when desired.

REFERENCES

Cervelli, J., K. Blaedel, G. Koide, and C. Radewan, "Maintenance Manual for Gas Metering System 1 at Building 343," Lawrence Livermore National Laboratory, (1983).

Koide, G., C. Radewan, K. Blaedel, and J. Cervelli, "High Pressure Computerized Gas Metering Manual," Lawrence Livermore National Laboratory, (1982).

ACKNOWLEDGEMENTS

The gas metering system was initially proposed by Joe Cervelli who managed these two projects for the High Pressure Test Facility. Clark Radewan did all of the electronic and computer interfacing and wrote the control algorithms of the metering valve and the graphic routines of the system diagram. The mechanical hardware subsystem which includes the Annin valve was designed and modified by Kenneth Blaedel. For System 2, Douglas Bell modified the software for System 1 and wrote additional routines to accommodate deuterium gas. Many additional features with keyboard interactions were made.

Since the gas metering systems required a multidisciplinary design and approach, the author also thanks the following organizations: (1) High Pressure Facility of the Nuclear Explosives Engineering Division, (2) Design Section of the Engineering Sciences Division, (3) Material Analysis Group of the Nuclear Energy Systems Division, (4) Micro/Mini Group of the Applications System Division, and (5) the secretaries of the High Pressure Facility and the Secretarial Pool.

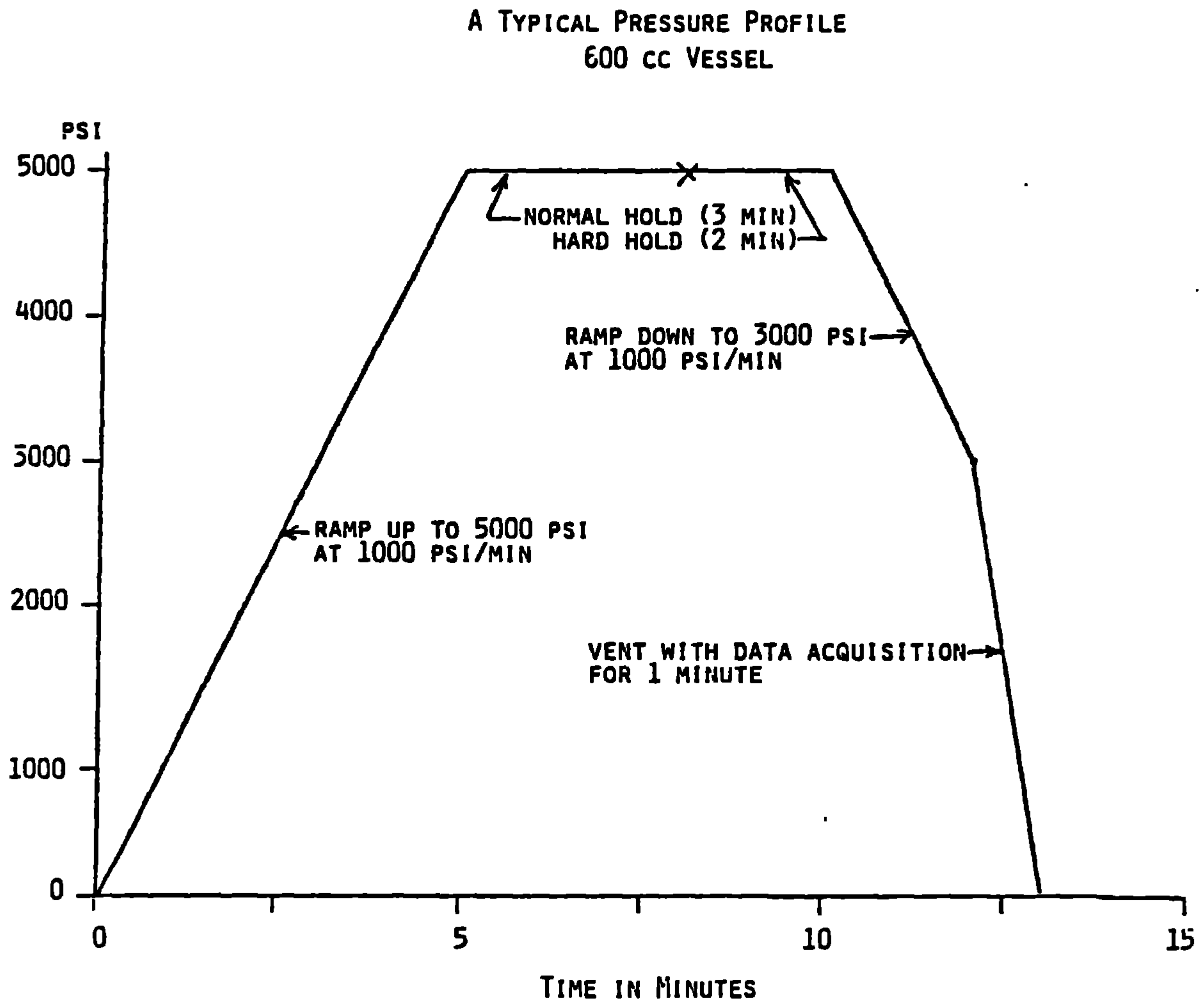


Figure 1. A Typical Pressure Profile

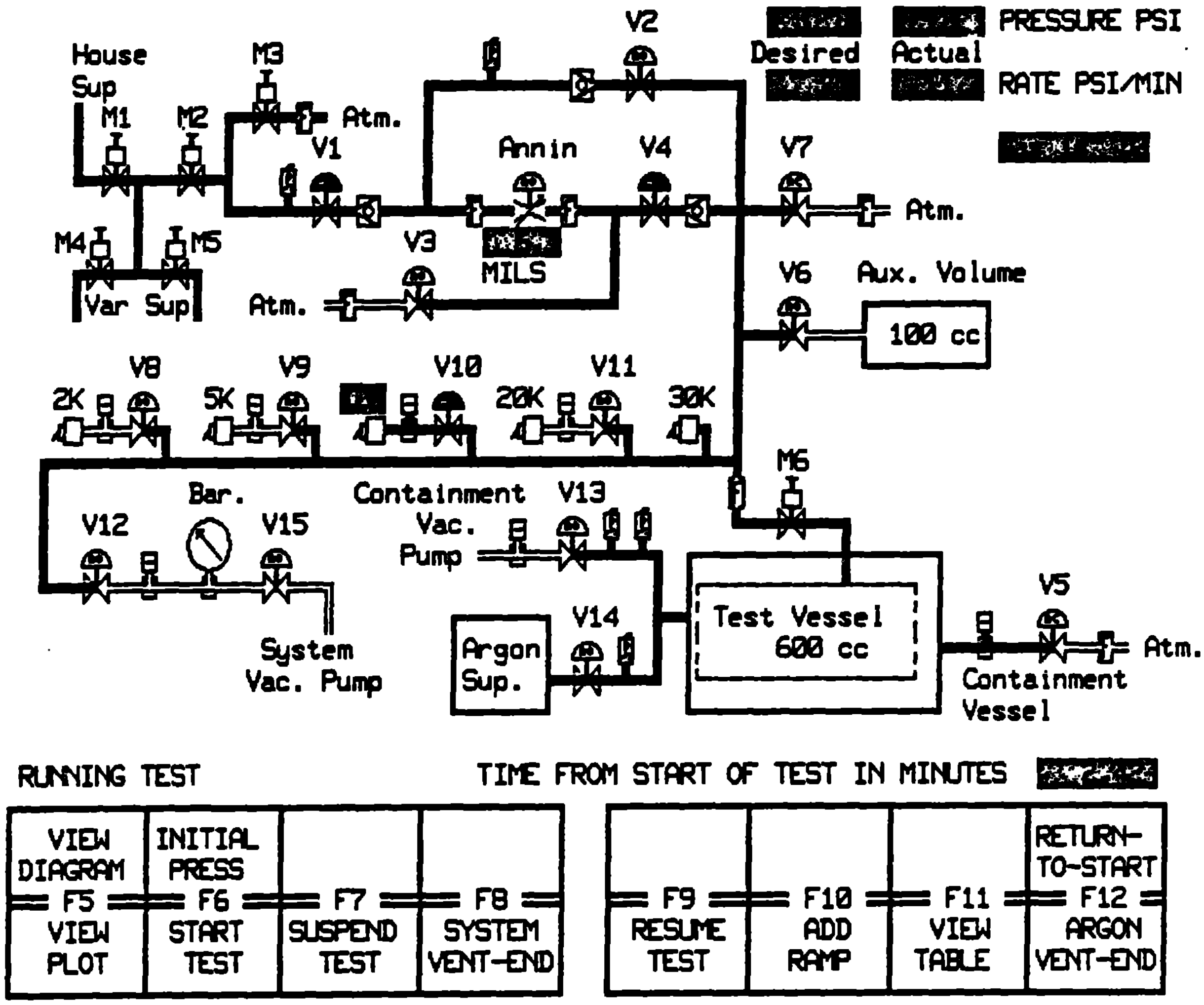
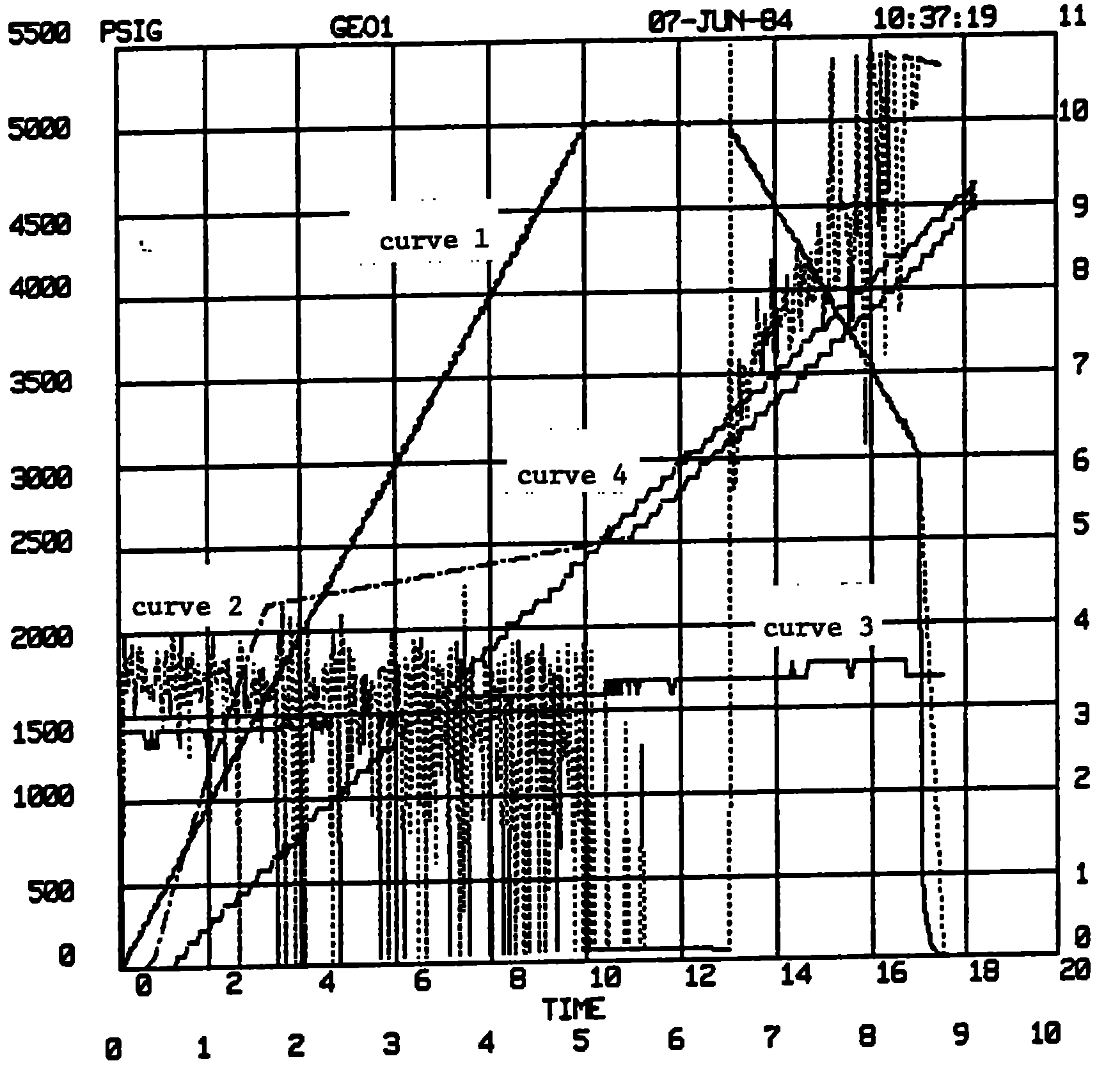


Figure 2. Diagram of System



VERTICAL AXIS						HORIZONTAL AXIS				
# TP	MINIMUM	MAXIMUM	SCALE	UNIT	TP	MINIMUM	MAXIMUM	SCALE	UNIT	
1 P	0.00	5.50E+03	500.	PSIG	T	0.00	20.	2.00	TIME	
2 L	0.00	20.	1.82	MILS	T	0.00	20.	2.00	TIME	
3 S0	15.	30.	1.36	DEGC	T	0.00	20.	2.00	TIME	
4 S3	0.00	1.50E+02	13.6	MI/I	P	0.00	5.50E+03	550.	PSIG	

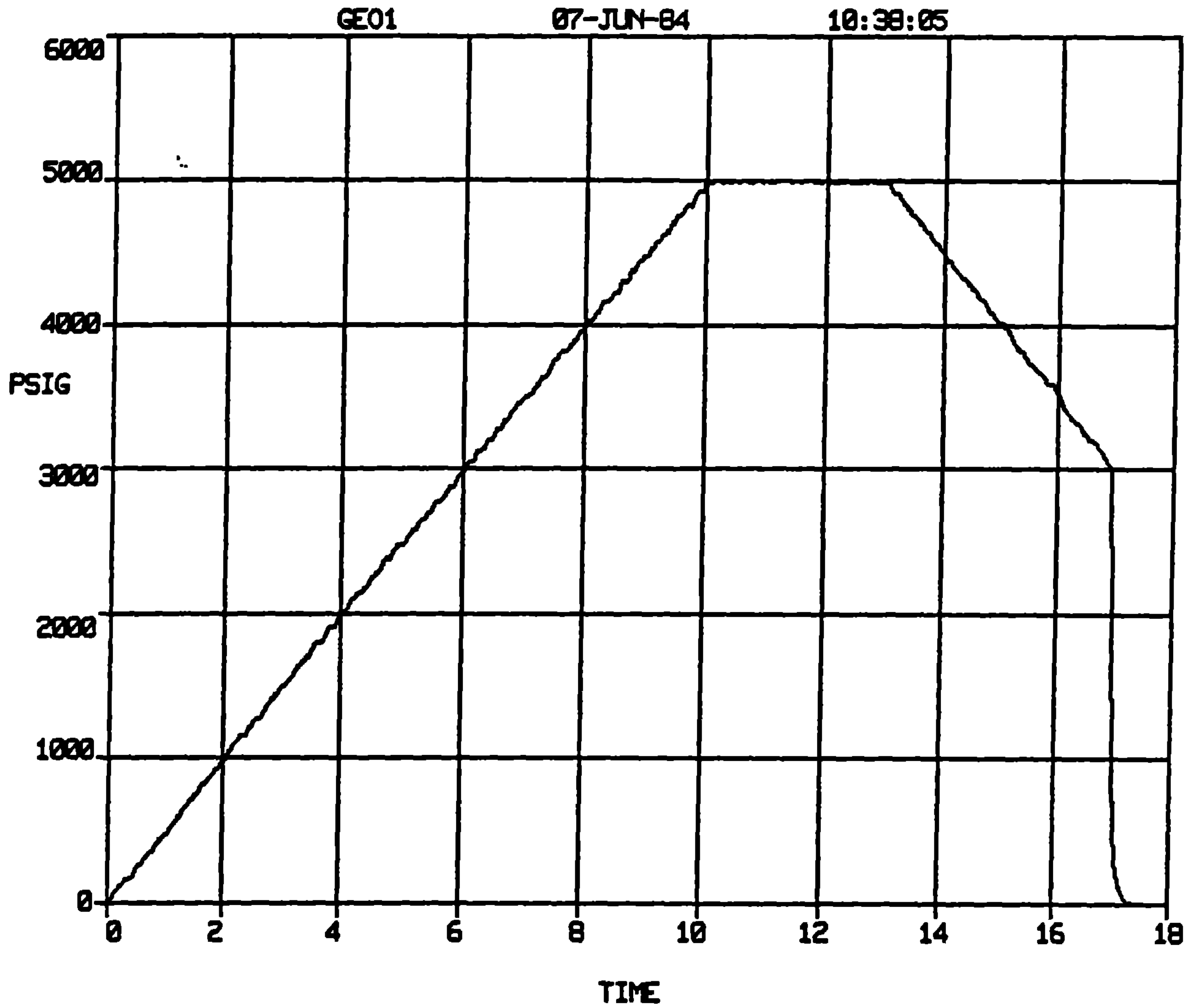
T=TIME IN MINUTES
P=SYSTEM'S PRESSURE IN PSIG
L=LVDT IN MILS
F=USER'S FAST A/D CHANNEL
S=USER'S SLOW A/D CHANNEL

Figure 3. Results of Real-Time Plots
curve 1 system pressure versus time
curve 2 displacement of metering valve versus time
curve 3 temperature of tube versus time
curve 4 strain versus pressure

TABLE OF USER'S TRANSDUCERS

CH #	VALUE	UNITS	CH #	VALUE	UNITS
LVDT	5.672	MILS	PRESS	2308.	PSIG
S 0	18.85	DEGC	S 1	16.70	DEGC
S 2	54.27	MI/I	S 3	53.05	MI/I
S 4	2256.	PSIG	S 5	0.1847	MILS

Figure 4. Table of Current Values of All Transducers



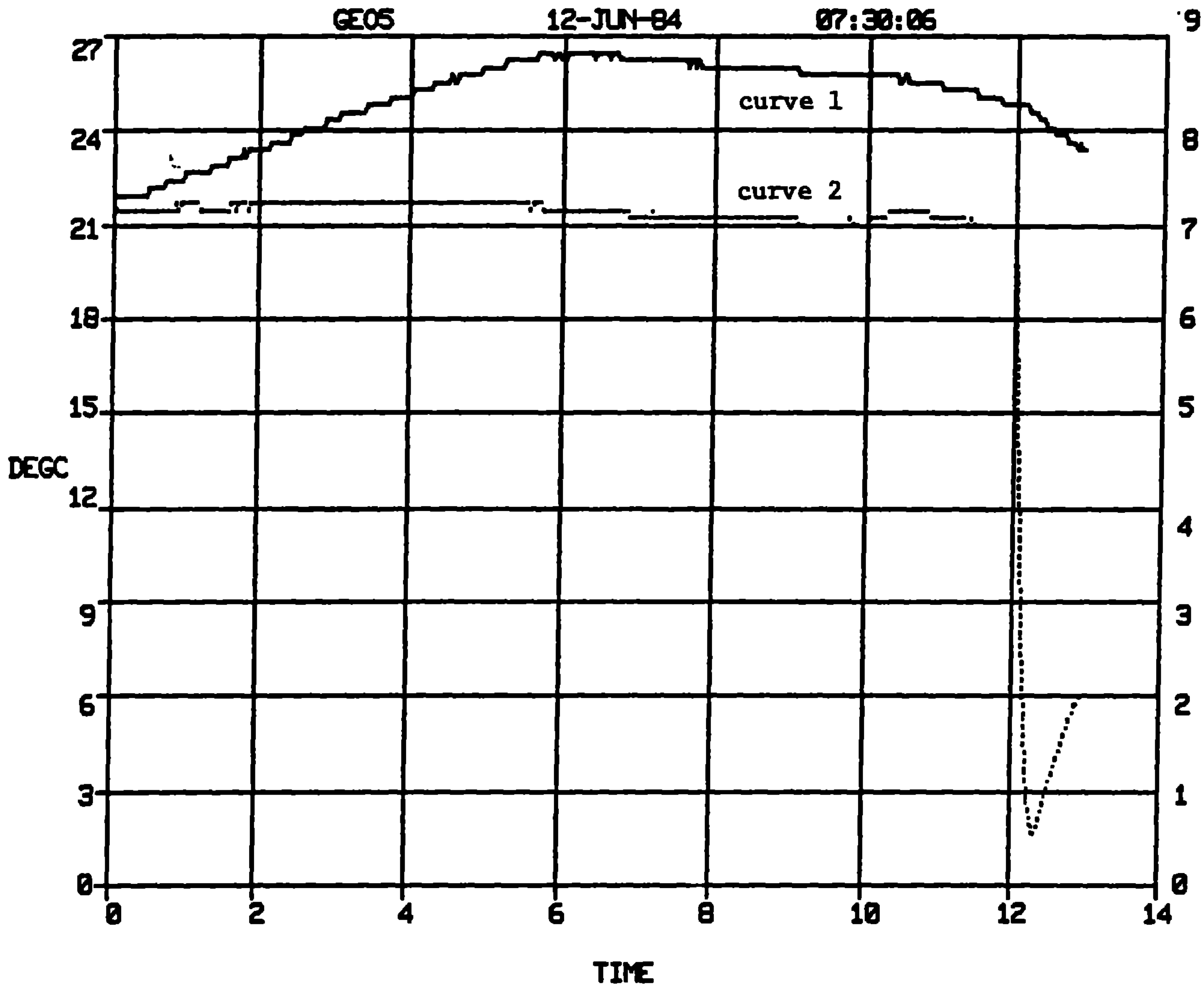
EXPERIMENTER : KOIDE OPERATOR : BROOKS

INNER DIAMETER OF TUBE (MILS) 62.0 VESSEL VOLUME (IN**3) 600.
LENGTH OF TUBE IN INCHES 60.0

HORIZONTAL AXIS
TIME IN MINUTES

VERTICAL AXIS
SYSTEM'S PRESSURE (PSIG) 0.000 0.503E+04 838.

Figure 5. Post-Experimental Plot of Pressure versus Time



EXPERIMENTER : KOIDE

OPERATOR : DAN

INNER DIAMETER OF TUBE (MILS) 62.0

LENGTH OF TUBE IN INCHES 60.0

VESSEL VOLUME (IN**3) 600.

HORIZONTAL AXIS
TIME IN MINUTES

VERTICAL AXIS

SLOW A/D CHANNEL #	0 (DEGC)	0.000	27.0	3.00
SLOW A/D CHANNEL #	1 (DEGC)	0.000	27.0	3.00

Figure 6. Plots of Temperatures in Degree C versus Time
curve 1 temperature of tube attached to test vessel
curve 2 temperature of vessel